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AUDIT OF SEPTIC TANK PERFORMANCE

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Abstract

The paper discusses a research project on septic tank treatment performance and an evaluation of factors that influence performance. Outcomes derived lay the groundwork for improved regulatory strategies for on-site domestic sewage treatment in Queensland's Logan City Council area. Key factors, which influence system performance, such as effluent quality, householder maintenance practices and site characteristics, were evaluated during the study. This research is expected to contribute to providing a rational basis for strengthening regulatory strategies governing on-site sewage treatment and furnish a specific focus for undertaking public information strategies relating to septic tank operation and maintenance.

Based on the outcomes of the study, a number of important conclusions were derived and recommendations made. The householder survey revealed that there is very limited appreciation of the need for regular maintenance of septic tanks. The testing of effluent from the distribution box showed that the performance of a large number of the septic tanks was unsatisfactory. Half of the septic tanks investigated were found to have excessive sludge build up leading to inadequate retention capacity and resulting in plug flow through the tank. The soil and landscape analysis undertaken of the sites indicate that most of the sites had characteristics which are not conducive for conventional subsurface effluent disposal.

Keywords

On-site systems, On-site sewage treatment, Septic tank performance, effluent renovation, householder maintenance, Septic tank audit.

1 Introduction

The safe and efficient management of sewage is essential for human wellbeing. However the provision of conventional sewage collection and treatment facilities can be prohibitive, particularly in sparsely populated areas. In these circumstances, the on-site treatment of sewage is the logical alternative. On-site sewage treatment systems are a common feature in most rural and urban fringe areas. In this regard, septic tank-soil absorption systems are the most widespread due to their simple operation and maintenance procedures. However despite the seemingly low technology of these systems, failure is common and it can lead to serious public health and environmental problems. Therefore it is imperative that stringent compliance criteria and practices are adopted in regards to their treatment performance and adequate precautions are taken to ensure householder adherence to these standards.

2 Research Project

2.1 Background

The research project undertook an audit in Queensland's Logan City Council area of septic tank performance and an evaluation of factors that influence treatment performance. A total of 18 septic tank locations in 9 different suburbs were selected for investigations. This provided a representative mix of site characteristics inherent to the area. All sites had separate greywater disposal systems and the septic tank was treating only blackwater. The study outcomes derived provide Logan City Council with an informed overview of the current status of septic tank performance in its jurisdictional area and lay the groundwork for the development of improved regulatory strategies for on-site domestic sewage treatment.

2.2 Aims and objectives

The primary aims of the research project were:

- to investigate the maintenance practices undertaken by householders;
- to ascertain householder perceptions on septic tank maintenance;
- to evaluate the quality of effluent being discharged into the disposal area; and
- to evaluate location specific factors which influence treatment performance.

The outcomes derived will contribute to achieving the following primary objectives:

- Provide a rational basis for strengthening regulatory strategies governing on-site sewage treatment in the Logan City Council area.
- Provide a specific focus for undertaking/strengthening public information relating to septic tank operation and maintenance.

2.3 Monitoring program

The tasks undertaken included the following:

1. Site inspection and householder survey to collect information relating to the treatment system such as its history, householder maintenance practices adopted and usage.
2. Inspection and measurement of septic tank contents such as the depth of scum, liquid layer or supernatant and sludge.
3. Investigation of septic tank detention time using an inert dye tracer.
4. Collection of effluent samples from the distribution box.
5. Collection of soil samples and mapping of soil horizons.

3 Testing Program

3.1 Objectives

Primary factors influencing wastewater treatment by septic tank-soil absorption systems are:

- The level of treatment taking place in a septic tank, which in turn determines the quality of effluent being discharged into the subsurface effluent disposal area.
- The ability of soil in the disposal area to undertake the treatment of pollutant residuals in the effluent, through chemical, physical and biological processes.

Consequently, the testing program undertaken had the following primary objectives:

- to determine the quality of effluent being discharged from the septic tank;
- the correlation of septic tank contents with householder maintenance practices; and
- to evaluate the suitability of the soil for undertaking effluent renovation based on site characteristics which influence treatment performance.

3.2 Rationale for the testing program

The overall focus of the research project was on the performance evaluation of septic tank systems together with the subsurface effluent disposal area. The effluent disposal area was included due to its crucial role. It is essentially the 'last line of defence' to prevent the contamination of water sources by sewage. The site characteristics play a crucial role in defining the performance of an on-site sewage treatment system. It is important that the effluent discharged to a disposal area is of satisfactory quality to ensure that clogging mat formation at the infiltrative surfaces is not accelerated. Secondly, it is important to ensure that the soil's capacity for the sorption of phosphorus is not exceeded and there is no excessive nitrogen enrichment of groundwater (Bouma et al. 1972; Kristiansen 1981; Reneau et al. 1989; Walker et al. 1973a,b). Therefore, the concentration of the primary pollutants in the effluent leaving the septic tank needs to be limited.

The measurement of septic tank contents and the evaluation of septic tank detention time were undertaken for the same reasons. Excessive sludge and scum build up can lead to reduced detention time and wash-out of sludge particles with the effluent, leading to the discharge of effluent of unsatisfactory quality to the subsurface disposal area. The soil and effluent parameters evaluated are listed in Table 1 below.

Table 1 – Effluent and soil parameters measured

parameter	effluent	soil	Reasons for selection
Total N	x		As specified in Table A7 of the Interim Code of Practice for On-site Sewerage Facilities (DNR 1999).
Total P	x		
BOD	x		
Suspended Solids	x		
pH	x	x	Surrogates for other chemical parameters
Electrical Conductivity	x	x	
Ca concentration	x	x	To calculate indicators of damage to the soil structure: Sodium Absorption Ratio, Exchangeable Sodium Percentage, Effective Cation Exchange Capacity for the soil.
Mg concentration	x	x	
Na concentration	x	x	
Al concentration		x	
K concentration		x	
Soil texture and structure		x	Possible indicators of the ability of the soil to renovate and percolate effluent through the soil.
Soil clay content		x	
Permeability		x	

4 Results and Analysis

4.1 Ongoing maintenance

As Table 2 below indicates, in the majority of sites (89%) there has not been any recent maintenance undertaken. It was noteworthy that some of the systems were over 10 years old and this essential maintenance practice has not been undertaken. Even in the case of the relatively newer systems, the householders did not appear to consider regular maintenance as an important factor for the satisfactory functioning of septic systems. Other studies of this nature have also derived similar conclusions (for example Jelliffe 1995).

4.2 Sludge depth

Criteria adopted to determine the theoretical sludge and scum build up (given in Table 2) included the need to ensure that there is sufficient clearance between:

- the scum layer and the outlet fitting to prevent the escape of scum with the effluent.
- the sludge layer and the outlet fitting to prevent the escape of sludge particles.

Figure 1 below further illustrates these criteria. The following conditions given in AS/NZS 1546.1:1998 were adopted for the calculations:

- sludge and scum accumulation is 50 L/person/year.
- 24 hour retention capacity for daily water-closet flows.
- the outlet fitting should extend to a depth of 330 mm below the invert of the outlet.
- the outlet fitting extending downwards to be not less than 75 mm below the scum layer.

Additionally, the following assumptions were also adopted:

- The sludge accumulation was taken to be 60% of the total sludge and scum volume (Caldwell Connell 1986).
- The minimum clearance between the outlet fitting and the sludge layer was taken as 175 mm (US PHS 1967).

Table 2 – Details of septic tank contents

Site no.	Sludge depth		Clear water depth		Scum depth		No. of people	System age (yrs)	Recent maintenance	Sludge removal (yrs)		Time available before next pump out (yrs)
	mm	%	mm	%	mm	%				Theoretical	Specified	
1	700	52	500	37	150	11	2	12+	No	6	5	1
2	750	56	350	26	250	18	6+	8+	No	2	2	0
3	50	4	1150	85	150	11	2	6	No	5	5	5
4	750	56	450	33	150	11	4	19	No	3	3	0
5	1,200	89	0	0	150	11	2	5	No	6	5	0
6	250	19	1075	80	25	1	5	1+	No	2	2	2
7	1,200	89	0	0	150		4	6	No	3	3	0
8	700	52	650	48	0	0	3	18+	No	4	4	1
9	650	48	625	46	75	6	2	5	No	6	5	1
10	800	52	325	24	325	24	5	14	No	2	2	0
11							3	12	No			
12	0	0	1350	100	0	0	2	11	Yes	6	5	5
13	1,150	85	0	0	200	15	4	5	No	3	3	0
14	130	10	1170	87	50	3	4	7	Yes	3	3	3
15	100	7	1250	93	0	0	2	8+	Yes	6	5	5
16	70		930		0	0	4	6	No	6	5	5
17	1,000	87	0	0	150	13	5	7	No	2	2	0
18	600	44	325	24	325	24	4	20	No	3	3	0

Note: The septic tank area in Site 11 was paved and measurements could not be taken

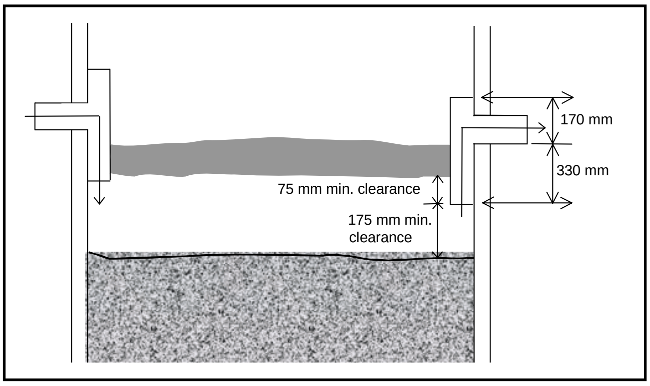

Figure 1 – Illustrating the criteria for determining sludge removal period

Eight of the 17 septic tanks (approx. 50%) were found to have excessive sludge and/or scum accumulated within the tank. Four of these septic tanks were completely filled with sludge and there was no storage capacity available for wastewater retention (refer Table 2).

4.3 Detention time measurements

The injection of two rare earth tracers with a fluorescent dye was undertaken in Site 7 in order to assess the detention time afforded to wastewater inflow. This location was selected, as the septic tank was found to be in need of immediate sludge removal. The result obtained from the tracer study is shown in Figure 2. One hour after the injection and the flushing of the toilet, a noticeable peak was observed at the distribution box for both elements. Subsequent flushing of the cistern at one and two hours after the tracer injection produced peaks of lower intensities with a delay of about one hour in both instances. This indicates significant short-circuiting of flow rather than the displacement of septic tank contents.

The very short detention period provided by the septic tank can be attributed to a contradictory phenomenon that was observed during the effluent testing program. Despite the minimal treatment that the wastewater would have been subjected to, effluent testing indicated comparatively favourable quality parameters. It is postulated that this is due to the almost immediate discharge of the wastewater from the septic tank as plug flow similar to the results obtained in the tracer study. The likelihood of a toilet usage event coinciding with a sampling episode would be quite remote. Therefore it is possible that effluent samples would have been collected at some point after peak flow when the pollutant concentrations were low. This hypothesis has added significance considering the fact that in systems treating only blackwater, the flow would be very intermittent. The carry over of accumulated sludge in the septic tank was not observed during effluent sampling. This could be due to a combination of conditions such as the compaction of the sludge layer and the forming of a hard crust thereby preventing its scouring due to the inflow of wastewater.

The observations noted, raise an important issue. Effluent sampling alone will not always be a reliable indicator of septic tank performance. Effluent sampling will only provide a ‘snap shot’ in time, which may not be the correct depiction of the septic tank performance. The depth measurement of septic tank contents in conjunction with effluent sampling will give a clearer picture of septic tank treatment performance.

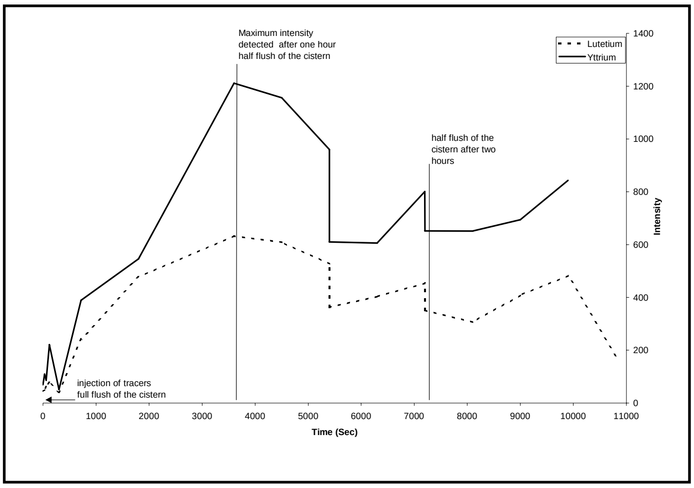

Figure 2 – Intensity of tracer vs time

4.4 Effluent Testing

A summary of results obtained is given in Table 3. Compliance values for effluent quality were derived after adjustments to the criteria specified in DNR (1999). These adjustments were necessitated as the criteria specified in DNR (1999) are for combined systems. The septic systems investigated under this project treated only blackwater. Consequently the wastewater flows from these systems have relatively higher pollutant concentrations but a lower flow volume. The basis for the adjustments undertaken is explained in Goonetilleke et al. (2000).

A number of issues were taken into consideration in evaluating effluent quality. Firstly, the Interim Code of Practice for On-site Sewerage Facilities (DNR 1999) stipulates that 90% of the effluent samples should comply with the specified criteria. Secondly, the sludge collected in the septic tank and hence the retention time provided to the wastewater has an impact on the effluent quality. However based on the results of the tracer study undertaken, it was found that when the retention time available is low, there is no mixing taking place in the septic tank. Consequently, a wastewater inflow resulting from a toilet usage event will flow through the system as plug flow. This means that an effluent sample collected in the distribution box may not reflect the level of treatment provided by the septic tank. As such, the sites where there was an excessive sludge build up was not included in the evaluation of effluent quality.

Table 3 – Analysis of effluent sampling results

Criteria	Sites in compliance
Removal of BOD only	3 (33%) - (Site 1, 8 & 16)
Removal of suspended solids only	5 (56%) - (Site 6, 8, 9, 14, & 16)
BOD and suspended solids together	2 (22%) - (Site 8 & 16)
Removal of nitrogen or phosphorus	0

Only a very small percentage of the sites were found to comply with the criteria for the removal of either BOD or suspended solids alone and an even smaller number for both parameters together. The criteria for evaluating effluent quality was based on DNR (1999) with appropriate modifications as noted above. The vast majority of the systems investigated are not performing their primary function, namely BOD and suspended solids removal. The situation was further aggravated by the fact that 50% of the sites investigated were already not even in a position to undertake the treatment of sewage.

4.5 Soil Testing

The investigations focussed on the ability of different soil types to undertake effluent renovation. The bulk of the soils within the Logan area have distinctly differentiated profiles, equivalent to the duplex profiles described by Northcote and Skene (1972) and could be classified as possible problem sites, ie. soils with coarse textured sand-sandy loam surface horizons fairly sharply separated from sandy clay or clay B horizons.

Detailed soil analysis was undertaken to evaluate soil physico-chemical characteristics at the study sites together with a comprehensive evaluation of site and landscape factors. The evaluation of results from the investigations undertaken revealed appreciable correlation between a number of significant parameters that influence the performance of an effluent disposal area (Goonetilleke 2000). These include effective cation exchange capacity (ECEC), dominance of exchangeable Ca or exchangeable Mg over exchangeable Na concentration, Ca:Mg ratio and dispersiveness (ESP or Emerson test).

In conjunction with the chemical characteristics of the soil, accurate recording of the physical characteristics such as colour, texture and structure within the soil profile assisted in evaluating the drainage characteristics at a site. Therefore it is important that physical characteristics are considered together with the chemical characteristics in order to characterise a problem site. Sites were categorised, initially by their landscape position and other site factors. Wherever the soil profile evaluation supported the drainage characteristics of the site as favourable, no further detailed chemical analysis was considered necessary. In the case of poor drainage, detailed soil chemistry can be a valuable tool in predicting site suitability for effluent disposal. Very poorly drained sites can be deemed unsuitable for on-site sewage disposal especially in small lot developments, without further analysis.

5 Recommendations to Council

The householder survey undertaken clearly illustrated the fact that the overwhelming majority (89%) were unaware of the correct operational and maintenance practices for septic tanks. These conclusions were confirmed beyond doubt after the inspection of the septic tanks. Half the sites inspected were found to have excessive sludge accumulated, thereby not being able to provide adequate retention time for sewage treatment. This highlighted the need to undertake a regular householder awareness program on the correct septic tank maintenance practices.

Secondly, in order to ensure compliance with accepted practices, it was also recommended that the householder awareness program should be linked directly to a stringent monitoring program to be undertaken by Logan City Council. The two programs should commence together and should complement each other. As part of the monitoring program, the maintenance of a register or database of individual onsite treatment systems should also be considered. The inspection of septic tanks, including sludge depth measurement should be an integral part of the monitoring program. Additionally, performance based strategies should be adopted in the planning and design of septic tank-soil absorption systems. Guidelines in this regard are provided in AS/NZS 1547:2000, ‘On-site Domestic Wastewater Management’. However there are significant practical difficulties involved in implementing these recommendations. After extensive deliberations, the Logan City Council has now decided to undertake a comprehensive householder awareness program. The implementation of a stringent monitoring program has been deferred for the present and pending the outcome of the present. Additionally, a new research project has recently commenced which will evaluate land suitability for effluent disposal based on soil and site characteristics with a view to developing performance based managed strategies for sewage effluent disposal.

6 Conclusions

The article has discussed the findings of a study undertaken to evaluate the treatment performance of septic tanks treating blackwater in the Queensland's Logan City Council area. The need for adopting regulatory strategies to ensure the satisfactory operation and maintenance of on-site sewage treatment systems was strongly reinforced by the results obtained. Based on the outcomes of the study, a number of important conclusions were derived and recommendations made.

These recommendations were based on a dual strategy. Firstly, it was to ensure that the house owners are better informed of the proper operation and maintenance of septic tanks. This process was to be strengthened by the implementation of a stringent monitoring program. Secondly, to initiate a performance based strategy for the planning, design and management of onsite sewage treatment systems. Considering the large number of variables involved, prescriptive practices for onsite sewage treatment are not feasible. Any strategies developed will need to account for the many factors involved. It requires the adoption of innovative approaches underpinned by a comprehensive knowledge base of the processes involved and subsurface and topographic features of the area, which influence sewage treatment.

Currently, the householder awareness program is being implemented and research has recently commenced on developing a performance based strategy for on-site sewage effluent disposal. The proposed monitoring program has been deferred for the present.

7 References

AS/NZS 1546.1:1998, On-site domestic wastewater treatment systems, Part 1: Septic tanks, Australian/New Zealand Standard, Standards Australia/New Zealand.

AS/NZS 1547:2000, On-site domestic-wastewater management, Australian/New Zealand Standard, Standards Australia/New Zealand.

Bouma, J., Ziebell, W. A., Walker, W. G., Olcott, P. G., McCoy, E. and Hole, F. D., 1972, Soil absorption of septic tank effluent, University of Wisconsin-Extension, Geological and Natural History Survey, Department of Soil Science and Bacteriology and Wisconsin Department of Natural Resources.

Caldwell Connell engineers, 1986, On-site wastewater disposal systems, Final Report, Water Authority of Western Australia, Perth.

DNR, 1999, Interim Code of Practice for on-site sewerage facilities, Department of Natural Resources, Queensland

Goonetilleke, A., Dawes, L. and Stuart, D., 2000, Audit of Septic Tank Performance for the Development of Management Strategies Physical Infrastructure Centre, Queensland University of Technology, Research Report No. 2000-08.

Jelliffe, P. A., 1995, A study of the performance of on-site treatment and disposal of systems in Maroochy Shire, February-March, 1994.

Kristiansen, R., 1981, Sand-filter trenches for purification of septic tank effluent: ll The fate of nitrogen, Journal of Environmental Quality, Vol. 10, No. 3, pp. 358-61.

Northcote, K. H. and Skene, J. K. M. 1972, Australian soils with saline and sodic properties. CSIRO Australia, Division of Soils, Publication No. 27

Reneau, R. B., Hagedorn, C. and Degen, M. J., 1989, Fate and transport of biological and inorganic contaminants from on-site disposal of domestic wastewater, Journal of Environmental Quality, Vol. 18, No. 2, pp. 135-44.

US PHS, 1967, Manual of Septic Tank Practice, US Public Health Service, US Department of Health, Education and Welfare.

Walker, W. G., Bouma, J., Keeney, D. R. and Magdoff. F. R., 1973a, Nitrogen transformation during subsurface disposal of septic tank effluent in sands: l. Soil transformations, Journal of Environmental Quality, Vol. 2, No. 4, pp. 475-9.

Walker, W. G., Bouma, J., Keeney, D. R. and Olcott, P. G., 1973b, Nitrogen transformation during subsurface disposal of septic tank effluent in sands: ll. Ground water quality, Journal of Environmental Quality, Vol. 2, No. 4, pp. 521-25.